a-SiGe:H films and devices deposited by HWCVD at low filament temperatures

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Outline of presentation

- Structure of HWCVD a-SiGe:H films quite different than that previously reported for PECVD films

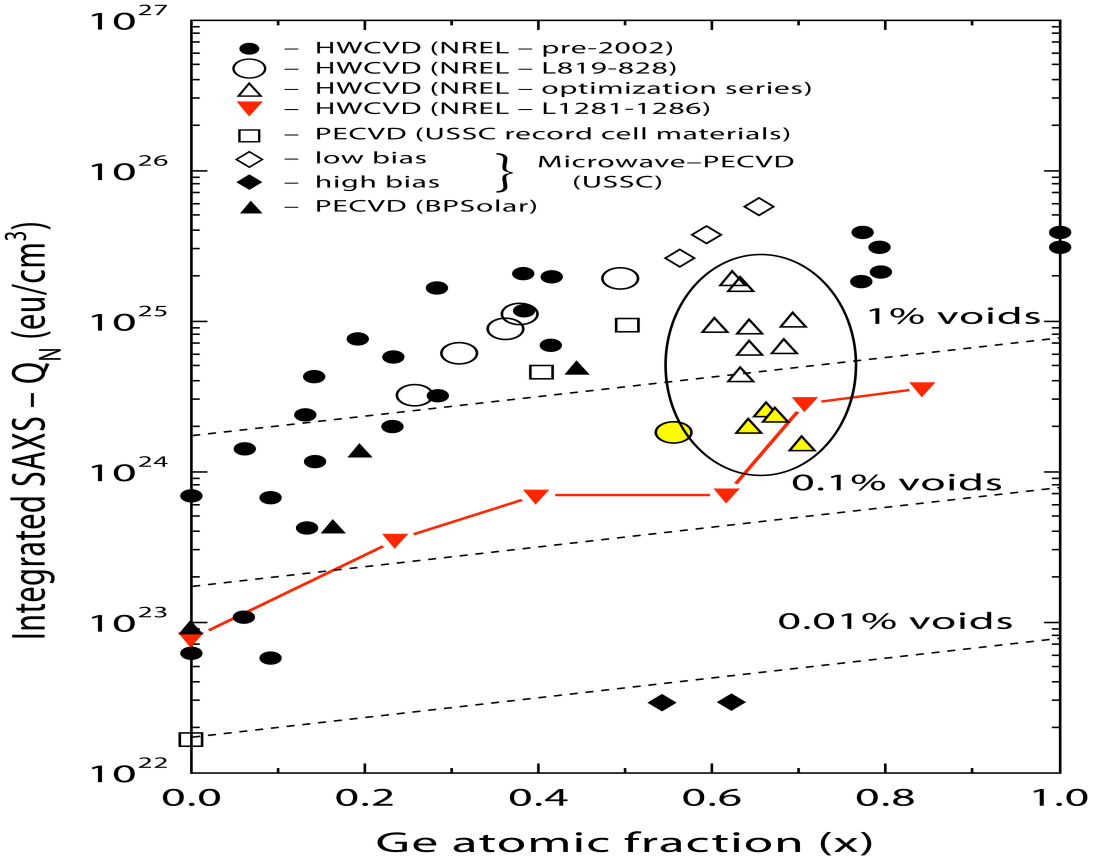
- We have an oxygen (O) contamination problem that has definitely impacted our film properties, and by implication our device results

- In spite of our O contamination, our device results are improved relative to those deposited previously

- give you one interpretation of our O 'source'

Structure - I (SAXS)

Low T_F and low T_S produce lower SAXS signal over entire range of film Ge contents



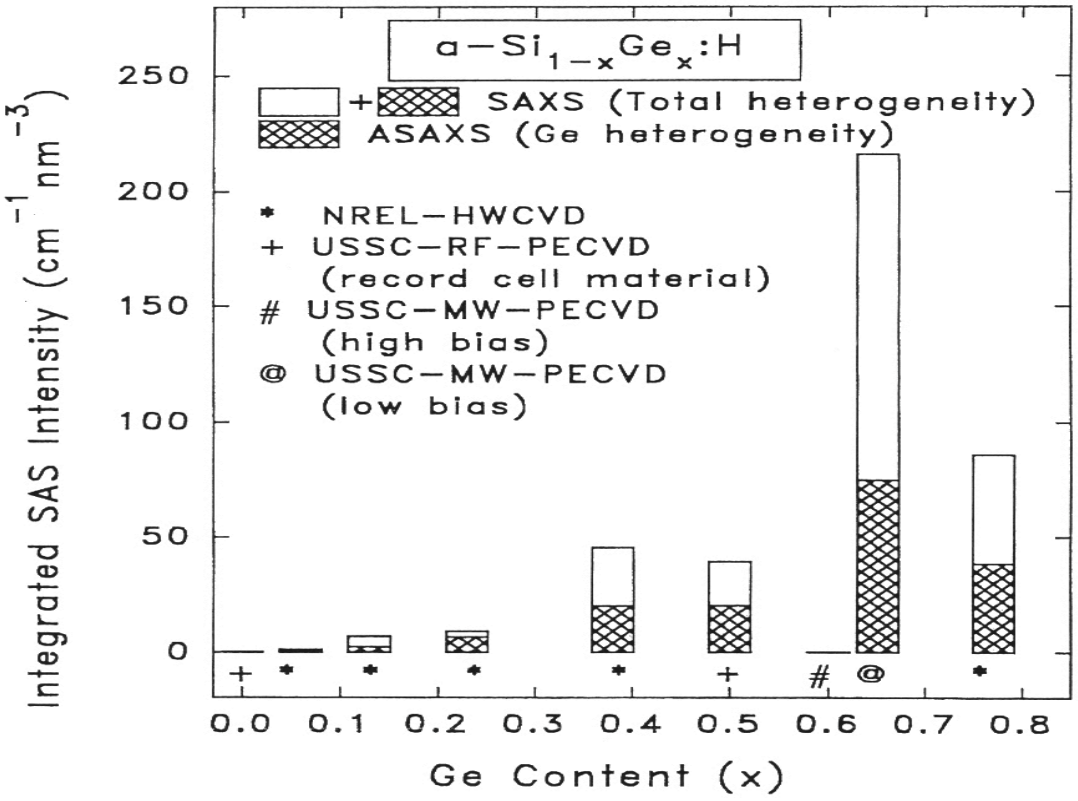
SAXS measurements - D.L. Williamson (CSM)

BONUS - Optimized [low T_F] HWCVD films also exhibit lower Ge-Ge clustering than optimized PECVD films - Anomalous SAXS (ASAXS)

Background:

- Un-optimized (high T_F) HWCVD films exhibit ASAXS signal ~ 50% of total signal

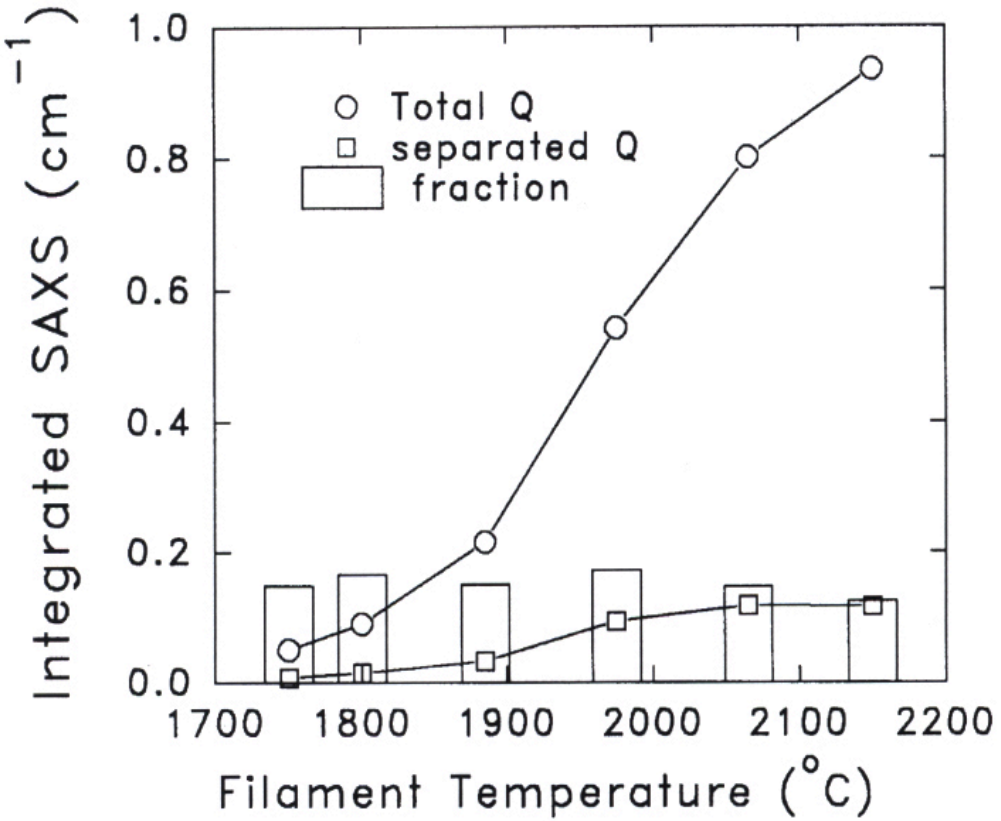
- Similar % for optimized PECVD films as well (**INCLUDING THOSE WITH H_2 DILUTION**)



D.L. Williamson, NREL Report SR-520-31908 (2002) 50.

Structure - II (ASAXS)

Optimized HWCVD films (low T_F, low T_S) now also exhibit lower ASAXS

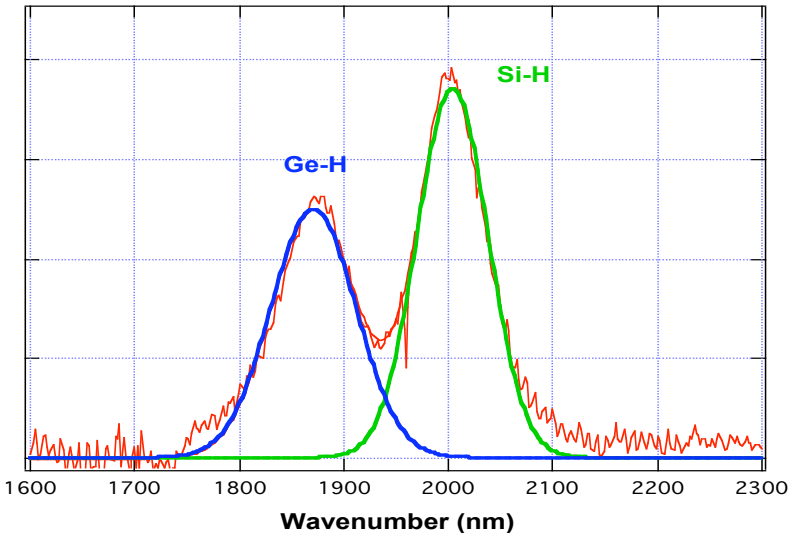


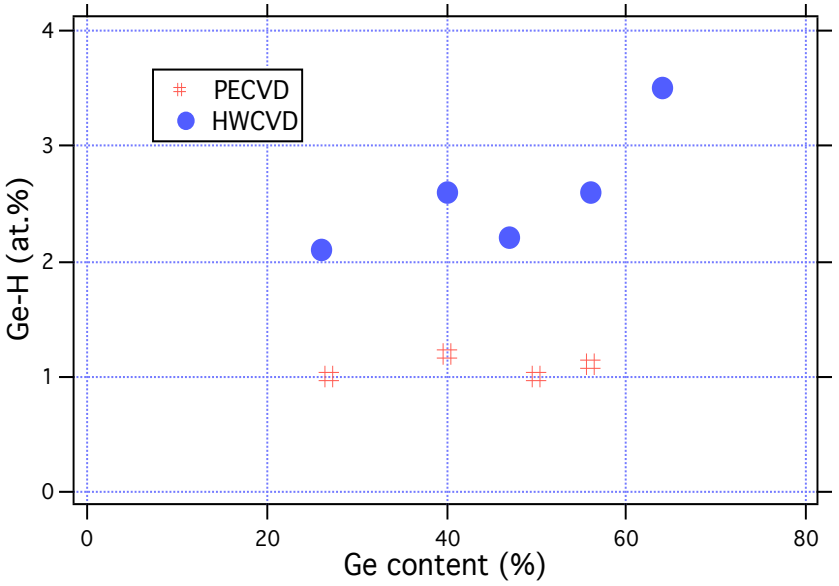
Fraction of SAXS intensity due to Ge-Ge clustering now only < 20%

Structure - III (Ge-H bonding)

More Ge-H bonding for HWCVD versus PECVD films

Stretch mode ‘signatures’ for a-SiGe:H

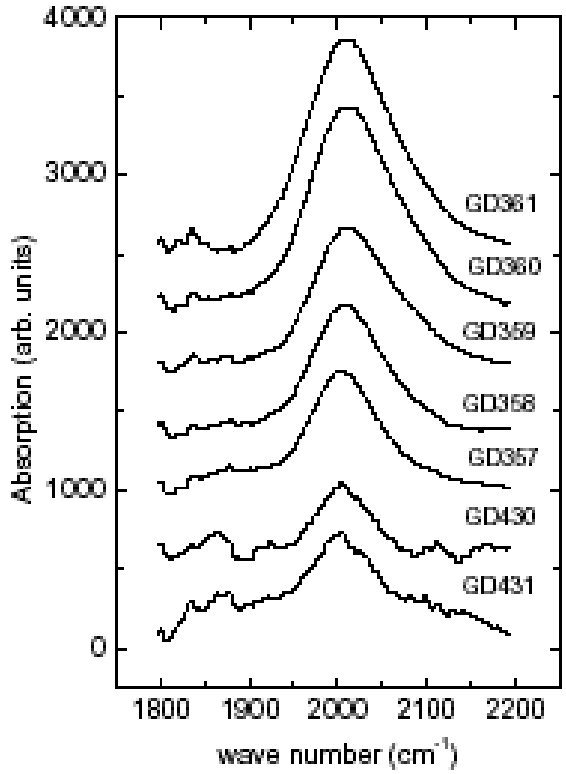




PECVD (Kyoto) 1999

Another comparison w/ team member

Univ. Toledo (ICAMS 2001)
(PECVD)
(high dilution (30), R_d < 1Å/s)



Bandgap

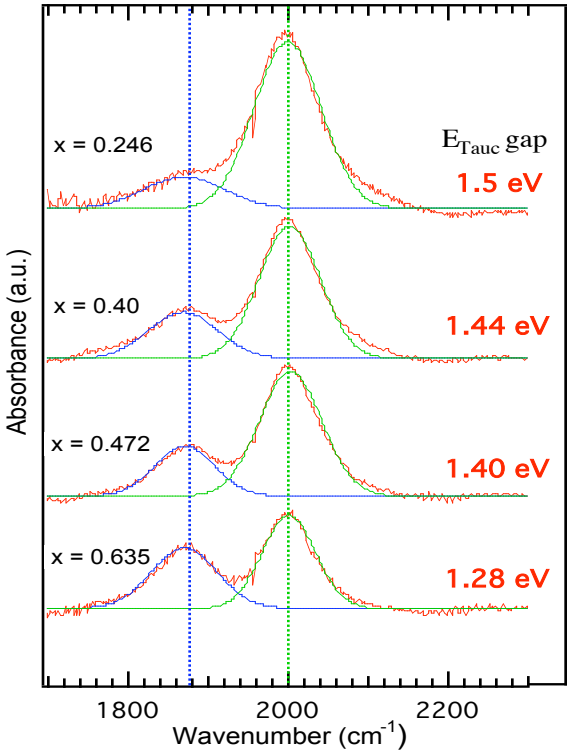
1.57 eV

1.50 eV

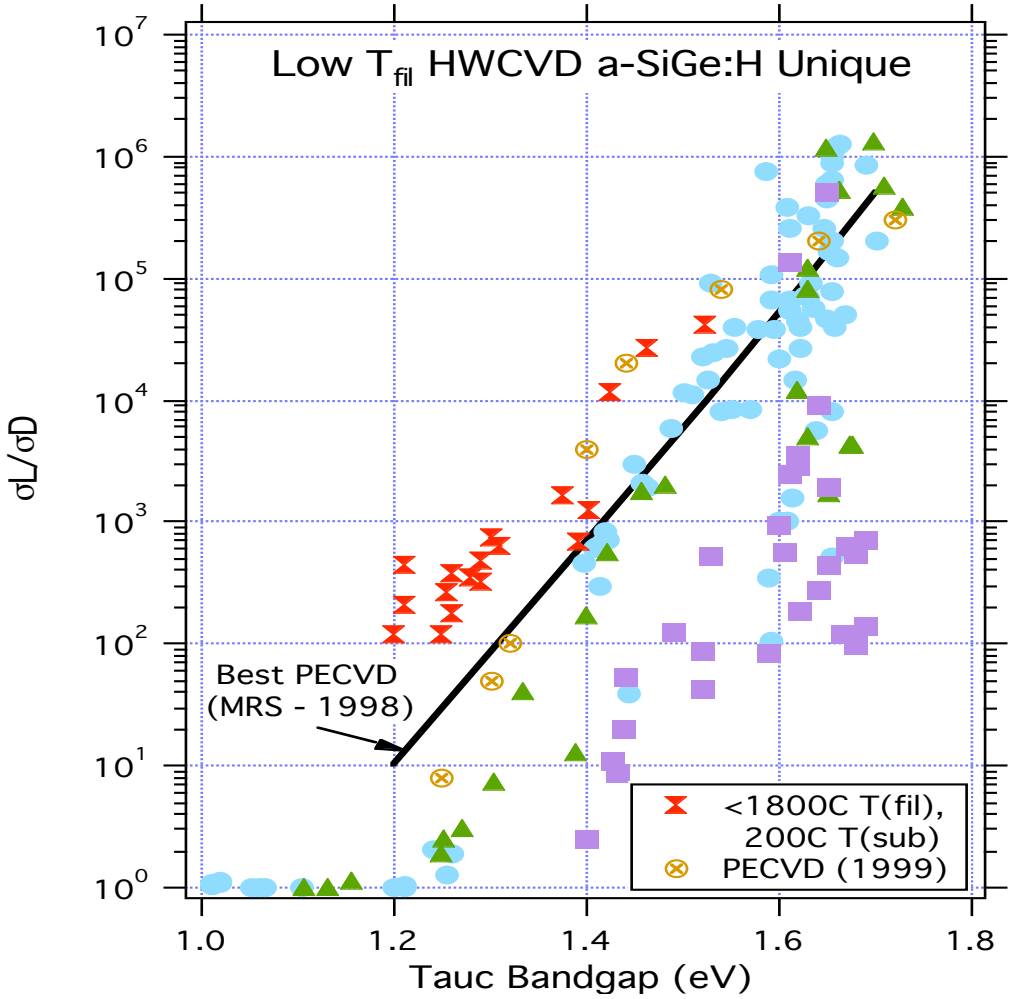
1.43 eV

1.37 eV

NREL (DOE 2004)
(HWCVD)
(low dilution (1), R_d ~ 2-3Å/s)

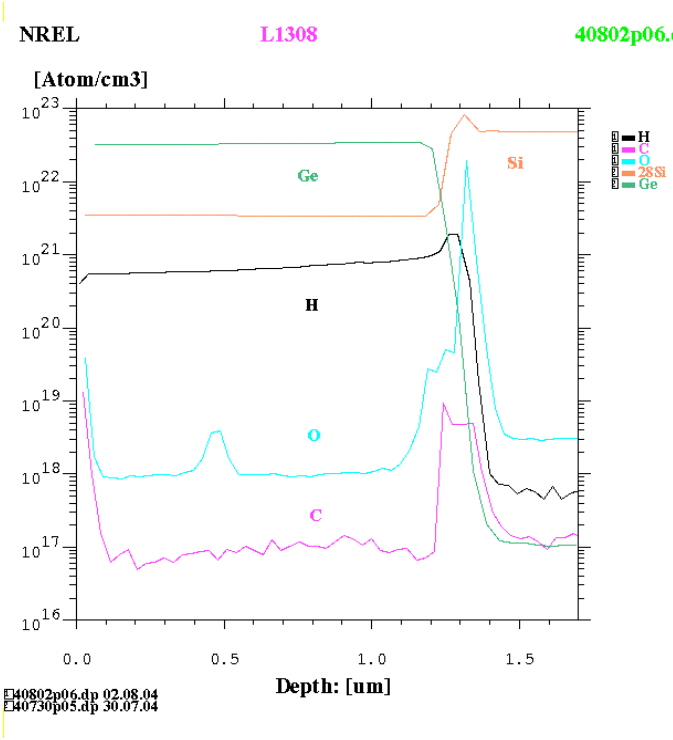


We believe these structural 'improvements' contribute to superior majority carrier collection for low bandgap materials

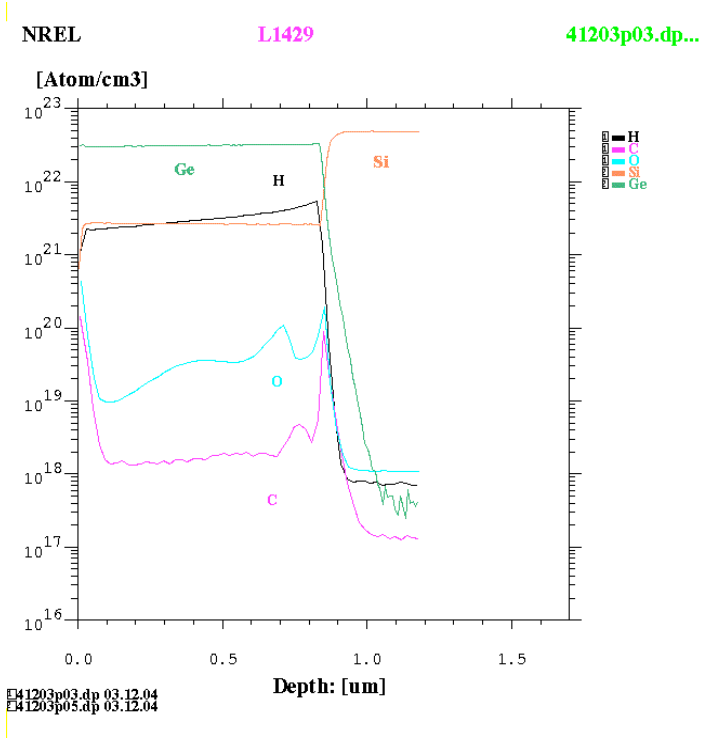


Oxygen contamination ‘issue’ -

SIMS O profiles of films identically deposited, but at different times

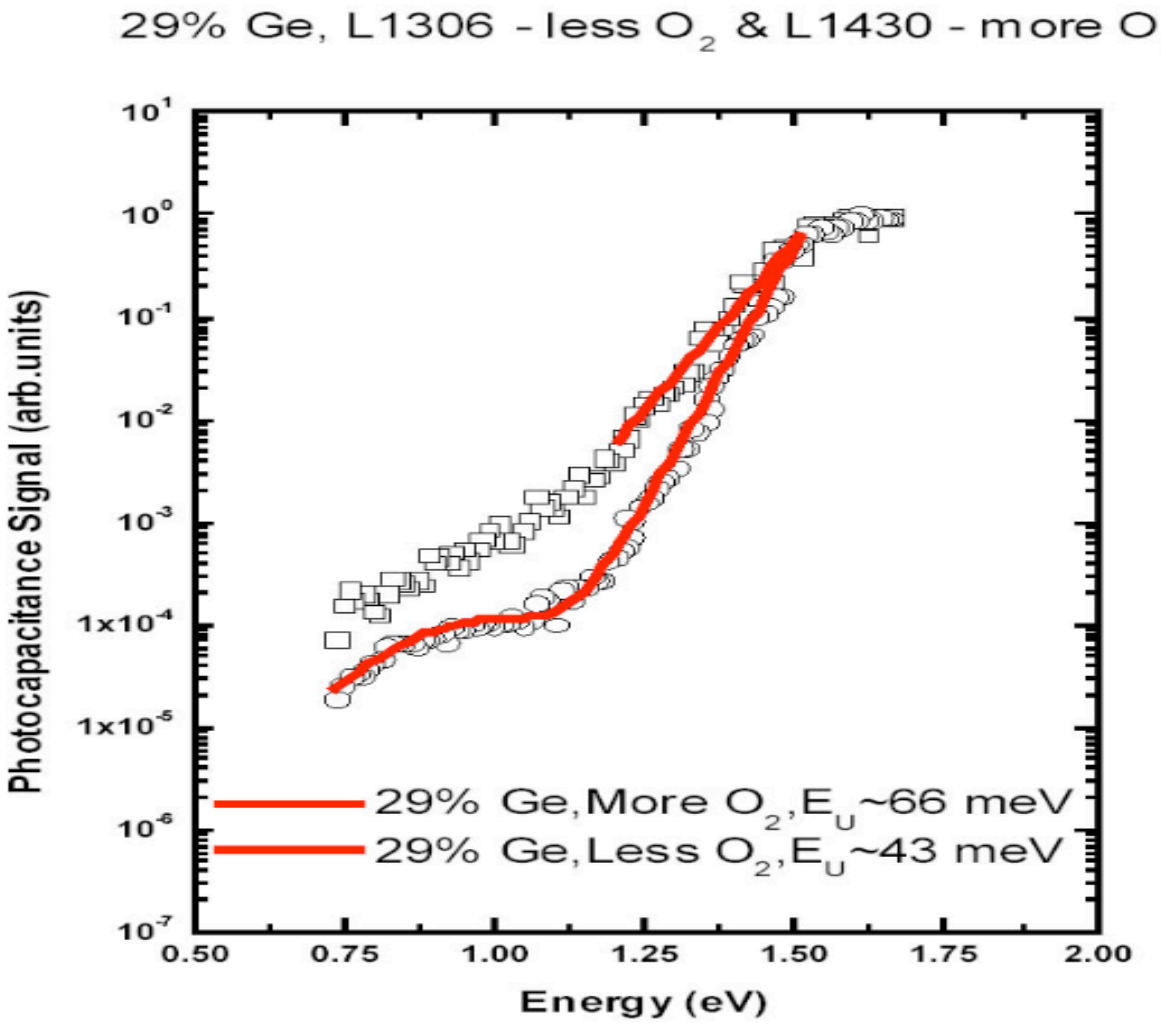


July ‘04 - O levels for films sent to Dave Cohen



Dec. ‘04 - O levels during device collaboration

Oxygen levels matter a lot!!!



D. Cohen - Univ. Oregon

Device improvements obtained in spite of oxygen contamination

Comparison (1) - NREL devices having QE (800nm) ~ 40%

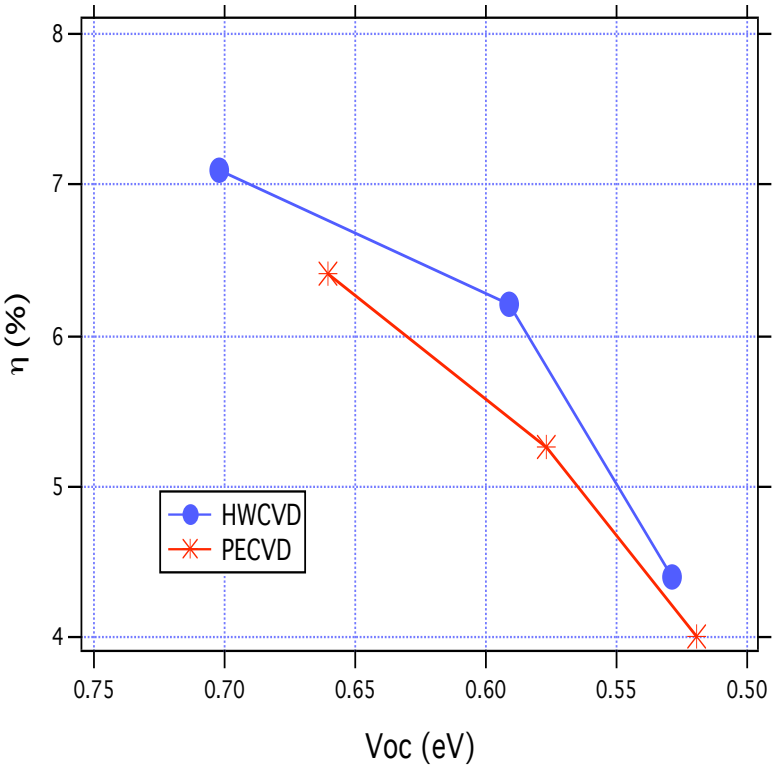
MRS 04 devices fabricated using a 0.38mm W filament operating @ 1800C

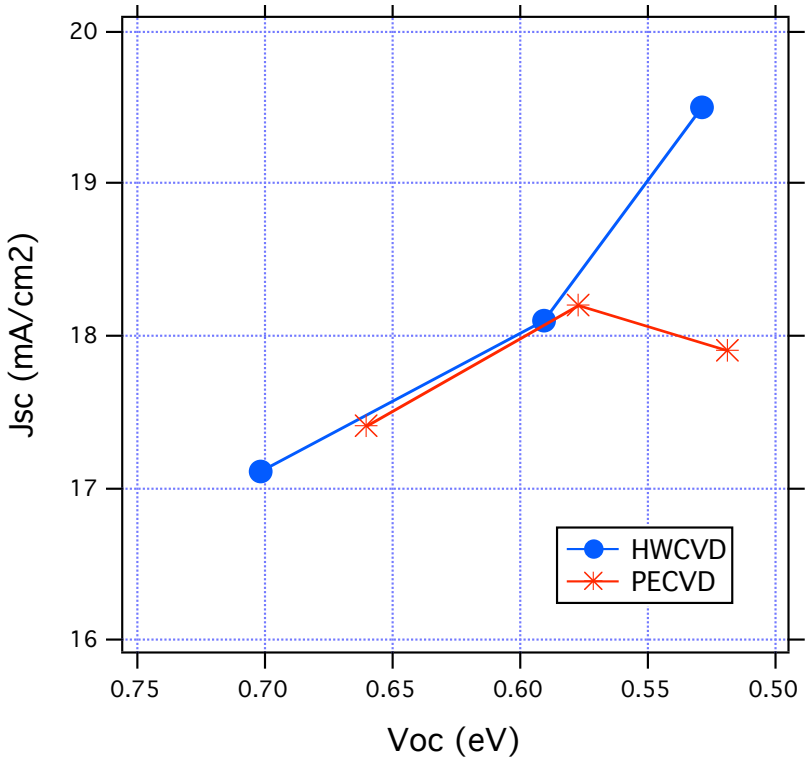
MRS 04 - Xu et al., MRS 808 (2004) 617.

	Single MRS 04	**Single L1403**	Double MRS 04	**Double L1415**
V_{oc} (mV)	.556	**.601**	.620	**.625**
J_{sc} (mA/cm^2)	19.59	**19.59**	20.03	**20.91**
FF (%)	.56	**.549**	.48	**.536**
Eff. (%)	6.10	**6.47**	5.95	**7.00**

‘In spite of O’ - Comparison 2

Univ. Toledo (ICAMS 19) - no bandgap profiling





Reminder - HWCVD R_d higher
(<1Å/s to 2-4Å/s)

Influence of grading scheme on device η for similar device V_{oc} (similar 'average' Ge content)

Device	Profile	J_{sc}	V_{oc}	FF	η (%)
L1422	None	18.9	.591	.553	6.2
L1403	Single	19.6	.601	.549	6.5
L1415	Double	20.9	.625	.536	7.0

One interpretation of O contamination - periodic contamination of house H_2 line

Only happens when use H_2 dilution

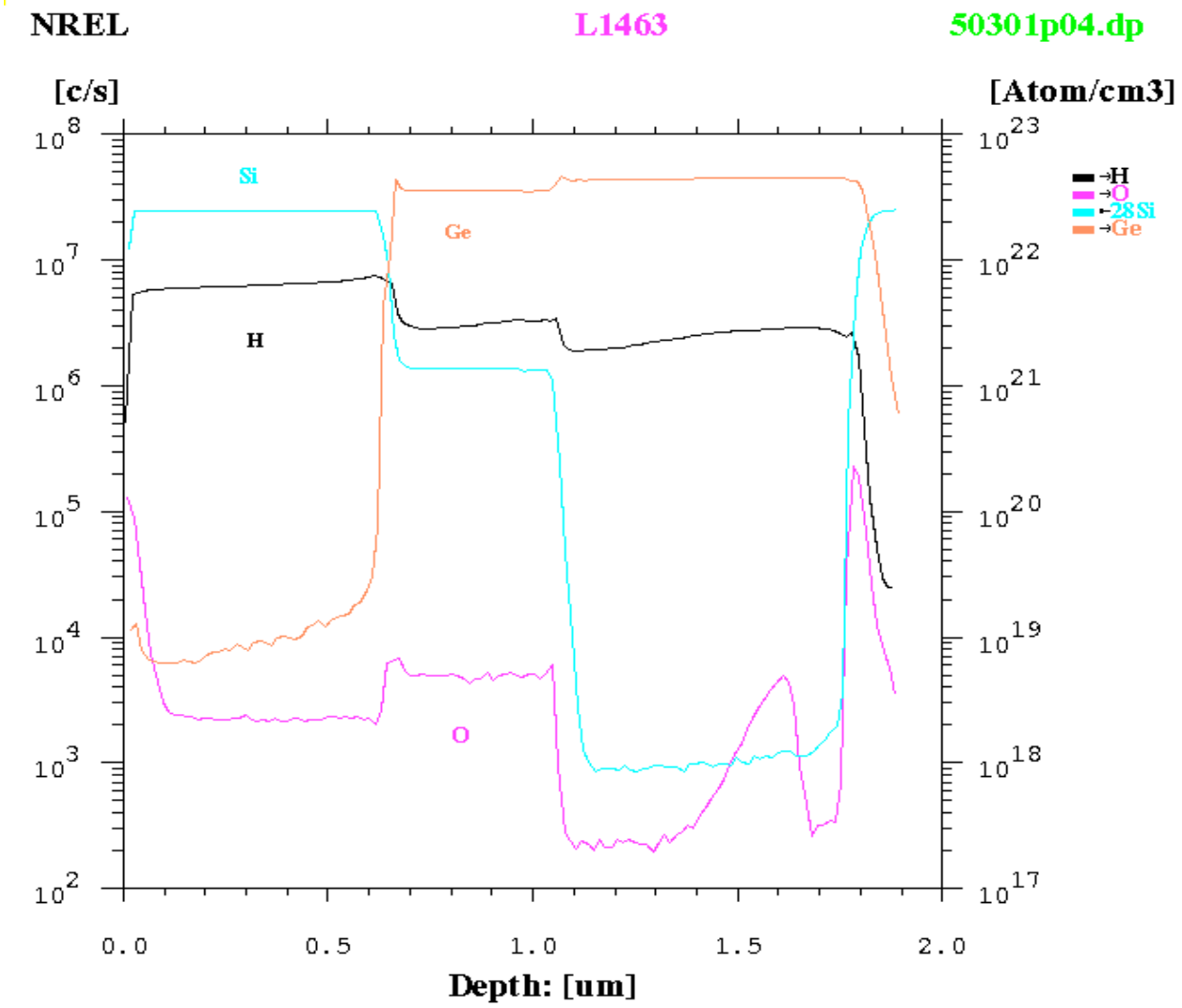
Can explain how single layer, identically deposited films contain different O levels when deposited at different times

Next stage of work:

- definitively identify and eliminate O contamination source

- repeat device fabrication with 'clean' i-layers

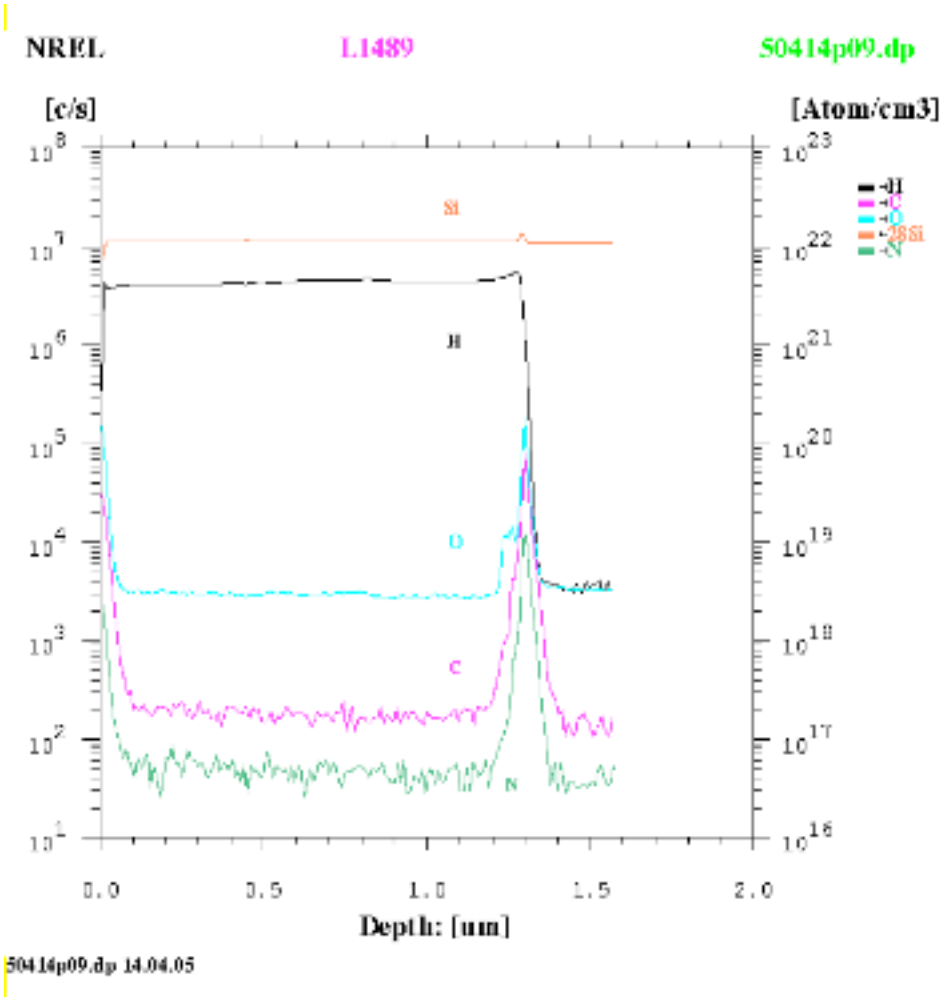
‘typical’ SIMS profile - three layer structure
Substrate/GeH_4/GeH_4 + SiH_4 + H_2/SiH_4



SIMS measurements following HWCVD 'treatments'

Film #	Filter	Bury layer	Filam. bake	Walls bake	New Filam.	O SiGe	O Si	Com-ments
1309						8e17		single
1445						~2e20		single
1456	**Yes**					5e19	1.5e18	3
1461	Yes	**Yes**				1e19	2.5e18	3
1462	Yes	Yes	**Yes**			7e18	2.5e18	3
1463	Yes	Yes	Yes			5e18	2e18	3
1464	Yes			**Yes**		5e18	2e18	3
1465	Yes	Yes	Yes		**Yes**	4e18	2e18	3
1475	**Yes**		**PECVD**			**5e19**	**5e19**	**No Ge**
1489	**Yes**	**Yes**	**Yes**			**3e18**	**3e18**	**No Ge**

H_2 line periodically contaminated???
Substrate/SiH_4/SiH_4 + H_2/SiH_4



O Contamination now gone????

SIMS O profiles for films measured by Dave Cohen